THE DISTRIBUTION AND ORIGIN OF DARK MATERIAL IN GALILEO REGIO, GANYMEDE: NEW EVIDENCE FROM GEOLOGICAL RELATIONSHIPS SEEN IN THE GALILEO DATA.

L. Prockter,[1] J.W. Head,[1] R. Pappalardo,[1] R. Greeley,[2] D. Senske[3], J. Moore[4], T. Denk[5] and the Galileo Imaging Team. 1Brown University, Dept. of Geological Sciences, Providence, RI 02912. [2]Arizona State University, Tempe, AZ. [3]JPL, Pasadena, CA. [4]NASA Ames, Moffett Field, CA. [5]DLR, Berlin, Germany.

At Voyager resolution, dark terrain on Ganymede (~50% of the surface) is seen to be made up of furrows, craters, palimpsests, and dark plains material. Based on Voyager data, a variety of origins have been proposed for the formation and evolution of dark terrain and the source of the darkening agent. New data from Galileo have shown that the dark material in Galileo Regio is very heterogeneous when seen at high resolution. Highest albedo material is present in the form of isolated knobs and massifs, crater rims and walls, furrow rims, and some plains units. Lower albedo material is found in crater and furrow floors, as plains units, as streaks on slopes, and as a hummocky unit interpreted to be crater ejecta. We here present new evidence from the Galileo G1 and G2 orbits (G2 provided stereo coverage over approximately one third of the G1 target area) as to the nature and origin of the dark material and the implications for dark terrain evolution.

Distribution of dark component: Many of the furrow rims, walls and crater walls show dark lineations oriented downslope (figure 1a). These lineations are narrow at the slope crest and widen at its base, suggestive of mass wasting. The dark nature of the streaks could be in part the result of grain size variations, or of differences in the amount of a silicate component. In some places we observe relatively sharp contacts between low albedo material apparently being shed from slopes and darker material at the foot of the slopes (figure 1b). These contacts may mark the spatial extent of the mass wasted material. The shedding of dark material from slopes indicates that at least some of the dark material has an origin related to mass wasting.

On south-facing slopes, very dark material characterizes the slope up to the vicinity of the crest (figure 1c). From stereo data we find examples of symmetrical bowl-shaped craters which have a bright wall on their north-facing slopes and a dark wall on their south-facing slopes (figure 1d). Contrasts are too extreme to be the result of photometric effects, therefore some other process must be occurring. It is possible that sublimation of volatiles from south-facing slopes has left a dark lag deposit and perhaps bright frost has been redeposited on north-facing slopes in a manner akin to that proposed by Spencer (1987). Very dark material is not seen on north-facing slopes, but it is difficult to deconvolve the effects of sublimation redistribution of material from the process of mass wasting.

Dark plains units are generally found in topographically low areas. The very darkest material is found in the floors of furrows and craters (1). A slightly higher albedo unit is distributed fairly uniformly throughout the region. These two dark units show some relations with other units which are consistent with embayment; there are some sharp, linear, occasionally lobate contacts between dark and bright units, and there are areas in which craters have been partially embayed by dark material. We find a bright plains unit which is heavily cratered and predates the remaining plains units.

An additional dark unit is found in the north-east of the imaged area (1). Hummocky dark material interpreted as ejecta (figure 1e) is seen extending radially away from a 50 km diameter crater just outside of the image. This hummocky dark material appears to have embayed preexisting topography except for high standing furrow and crater rims.

Origin of dark material and heterogeneity: *Evidence for meteoritic component addition:* If the albedo of the dark terrain is low because of the addition of a dark meteoritic component, a progressive darkening of the surface with age would be expected, except where it is renewed. The older heavily cratered plains units may have been emplaced as brighter units or may have become brighter with time, perhaps through frost deposition (2). The age of these plains puts constraints on addition of material from above; they may have been modified by the deposition of material but they have not been buried. Consequently, if meteoritic addition was significant in contributing to the low albedo of dark terrain, it must have been a significant process early in Ganymede's history. The removal of material downslope by mass wasting, revealing brighter material upslope, is the best evidence for the addition of some dark component which may be meteoritic material. The presence of a dark, silicate-rich sublimation lag may also be evidence for the addition of a meteoritic component (see next section).

Sublimation: Evidence for segregation of bright and dark material: The north/south-facing slope dichotomy may be explained through the process of sublimation and deposition (3,4). South-facing slopes could be subject to sublimation of volatiles (specifically H_2O vapor) from the regolith, leaving behind a dark, perhaps silicate-rich deposit. H_2O vapor may then be redeposited on the north-facing slopes, which, facing away from the insolation direction would be colder, allowing condensation to occur (2). Frost is a prominent feature in northern latitudes (5) where it is particularly prevalent on the north-facing slopes.

Evidence for cryovolcanism: The most persuasive evidence for volcanism is found in areas where sharp, sometimes lobate contacts are observed, for example in the ~20 km crater in the lower center of the image. This crater has a domed floor with a dark deposit exhibiting lobate margins in the south and east (figure 1f). We see several examples of lobate contacts between dark and lighter material at the foot of furrow walls, and some craters in this area show embayment relations (figures 1g, 1h). Cryovolcanism may not be a primary source of the dark plains material in the furrow floors, as these tend to be 'V' shaped in profile, rather than flat. No source vents are observed at this resolution.

Evidence for magnetospheric interaction/sputtering: There is some evidence that sputtering may be a significant process in the dark terrain of Ganymede (6). While the rate of ablation would be reduced by a lag deposit of rocky debris (7), the process of impact gardening would be expected to distribute this deposit throughout the regolith, thus negating the effects of the lag deposit. If sputtering rates are greater than the rate of thermal ice sublimation, rehomogenization of the surface would prevent the segregation of the dark material into bright frost and dark lag deposits (2). The presence of the north/south-facing slope dichotomy indicates that if sputtering is occurring in this region, it must be a less significant process than sublimation.

Summary: We find clear evidence that mass wasting is a significant process on the surface of Ganymede, although the extent of material transport, and hence resurfacing, possible through this process has not yet been determined. Sublimation processes are apparently significant on slopes, where frost deposition contributes to the brightness of north-facing slopes, while south-facing slopes are darkened due to an ice-free lag deposit. There is clear evidence that this process occurs in the northern latititudes of Galileo Regio (5). Some observations of lobate contacts may best be interpreted as evidence of cryovolcanism, but this does not appear to be widespread. Hummocky, low albedo ejecta is clearly seen to act as a resurfacing agent in the vicinity of a large crater adjacent to the study area. Magnetospheric sputtering is not expected to make a significant contribution to the mobilization of dark material on the surface. The dark component of Ganymede's dark terrain may have originated through meteoritic contamination and we await other results from Galileo, specifically NIMS and SSI color observations, to better constrain the composition and distribution of the dark contaminant at different latitudes.

Future work and upcoming targets: Future work involves further deconvolving these different processes as it is likely that more than one of them has occurred within Galileo Regio. We will further examine the role of ejecta as a resurfacing agent, both here and in other areas of dark terrain. Impact melt may also be a contributing factor to the dark deposits on crater floors.

Future Galileo observations of dark terrain will aid in our interpretations; in particular G7 orbit observations of Nicholson Regio (180 m/pxl) and G8 imaging of Marius Regio (~150 m/pxl), along with observations of dark and transitional terrain at various latitudes and illumination conditions. Observations of grooved terrain will allow us to determine which of these processes also occur there and whether we can eliminate or confirm such processes as darkening agents in Ganymede's dark terrain.

References: (1) Prockter L. et al., this volume. (2) Spencer J.R. (1987), Icarus 69, 297 - 313. (3) Moore J.M., M.T. Mellon and A.P. Zent (1996), Icarus 22, 63 - 78. (4) Moore J., this volume. (5) Pappalardo R.T. et al., this volume. (6) Cheng et al., (1986), in *Satellites* eds .J.A. Burns & M.S. Matthews, p.403 - 436, Univ. of Arizona Press, Tucson, Arizona. (7) Shoemaker E.M. et al. (1982), in *Satellites of Jupiter* ed. D. Morrison, p.435 - 520, Univ. of Arizona Press, Tucson, Arizona.

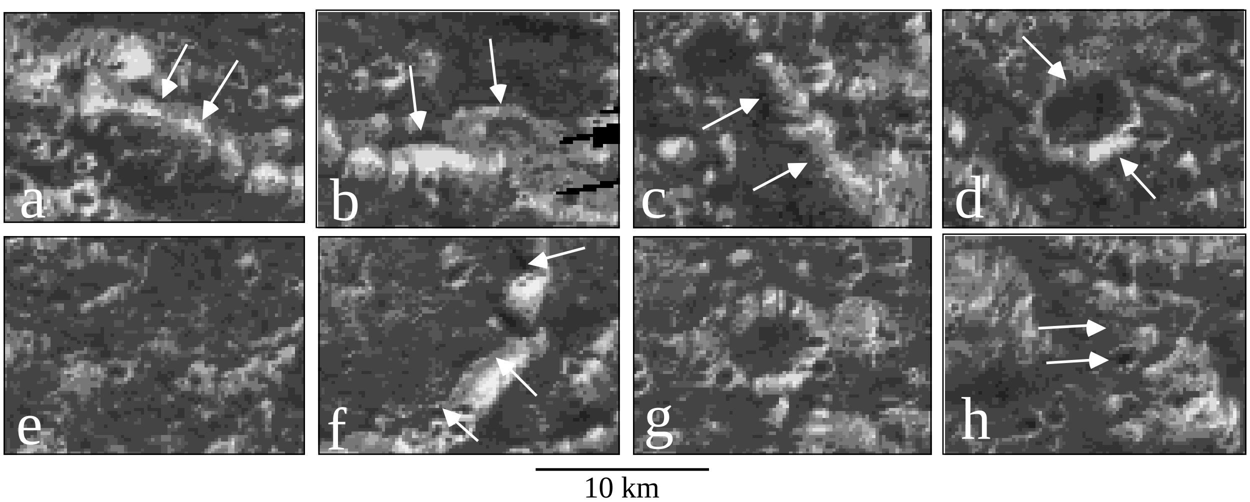

Figure 1: North is toward the top; arrows indicate features referred to in text. (a) Many furrow rims, walls and crater walls show dark vertical lineations oriented downslope. (b) Relatively sharp contacts between low albedo material apparently being shed from slopes and darker material at the foot of the slopes. (c) Many south-facing slopes are characterized by dark material from crest to base. (d) Stereo shows this crater to be symmetrical and bowl shaped. The distribution of dark and light material on its walls is not symmetrical and cannot be explained by photometric effects. (e) Hummocky dark material interpreted as ejecta. (f) ~20 km crater with domed floor apparently filled with dark deposit exhibiting lobate margins. (g and h) Craters embayed with dark material.